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Survival and growth of four Douglas-fir stock types 21 years after planting

by G.J. Krumlik and
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Ministry of Forests

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ABSTRACT

The experiment was established in 1962 near Lake Cowichan and Campbell River, B.C., to evaluate survival and growth of five Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) bareroot stock types: 1+0 spring sown, 1+0 autumn sown, 2+0, and transplanted 1+1. The fifth stock type was 1+0 autumn sown from a different seedlot. At each location there were three burning treatments (no burn, fresh burn, old burn), each located on two aspects (south and north).

The experiment was evaluated after the first, second, and third growing seasons. A report prepared after the third growing season concluded that there were no significant differences in survival and growth between 1+1 and 2+0 stocks; however, autumn-sown 1+0 stock had significantly lower survival and growth than 1+1 or 2+0 stock, and spring-sown 1+0 stock was significantly poorer than autumn-sown 1+0 stock. Differences in survival and growth were significant between north and south aspects and were greatest in the 1+0 spring- and autumn-sown stock classes. Survival was higher on north aspects but initial leader growth was longer on south aspects. Differences in survival among the three burning treatments were negligible, although significantly longer leader growth was measured on old burns. The differences in size among stock types were expected to disappear within 5 years after planting.

The experiment was re-evaluated after the 21st growing season. The differences in survival and height among stock types observed at 3 years remained almost unchanged 18 years later. Stock types 1+1 and 2+0 were not significantly different from each other; however, both 1+0 (spring- and autumn-sown) stock types had significantly lower survival and height than 1+1 or 2+0 stock types. Spring-sown 1+0 stock type was significantly poorer than autumn-sown 1+0 stock type in survival and height growth. The differences among three burning treatments or between two aspects were not significant.

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1 INTRODUCTION

This experimental project was established in 1962 under the title "Planting Stock Class Comparison Trial: Survival of Five Types of Douglas-fir Nursery Stock on Six Planting Sites"[1].

The objective of the experiment was to test survival and growth of five stock types planted on south and north Vancouver Island (vicinity of Cowichan Lake and Campbell River), on south and north aspects and on burned and unburned sites (Table 1, p. 10). The bareroot stock types were 1+0 spring sown, 1+0 autumn sown, and 2+0 and 1+1 transplants from seedlot B2/404/59 (Figure 1). The fifth stock type was autumn-sown 1+0 from seedlot B2/467/59. All stock types were produced at Koksilah Nursery in Duncan, B.C., during 1960 and 1961. The initial height of stock types is in Table 6, p. 14.

The three burning histories were: 1) unburned - an area logged 5-7 years before planting and not burned; 2) fresh burned - an area recently logged and burned the previous autumn before planting; and 3) old burned - an area logged and burned 5-7 years before planting. The intensity of the burn was not recorded; however, the requirement was that the burns should have left the areas relatively clean.

Each burning treatment was tested in two locations (near Lake Cowichan and Campbell River) and on two aspects (north and south) using two replicates. Altogether 24 experimental plots (two locations x three types of burning treatment x two aspects x two replicates) were established (Table 1, p.9).

Each experimental plot was planted with five rows of 50 seedlings, one row of each of the five stock types. The distance between rows was 1.83 m (6 ft), and between seedlings in a row 0.61 m (2 ft), making a plot 9.15 x 30.50 m (30 x 100 ft) large. The plots were laid out with the long axis across contours.

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[1]W.J. Revel. 1962. Planting stock class comparison trial: Survival of five types of Douglas-fir nursery stock on six planting sites. E.P. 586 Working Plan. B.C. Forest Service, Research Division, Victoria, B.C.

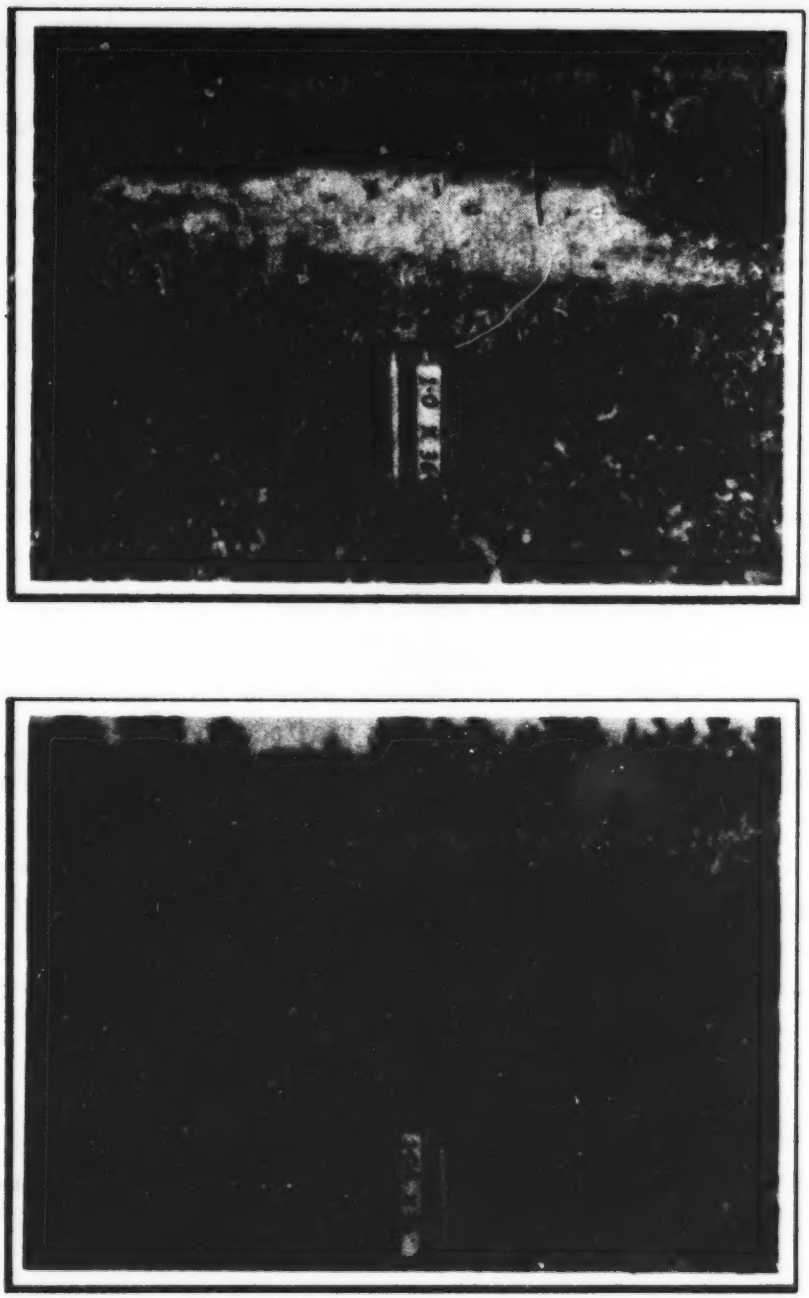
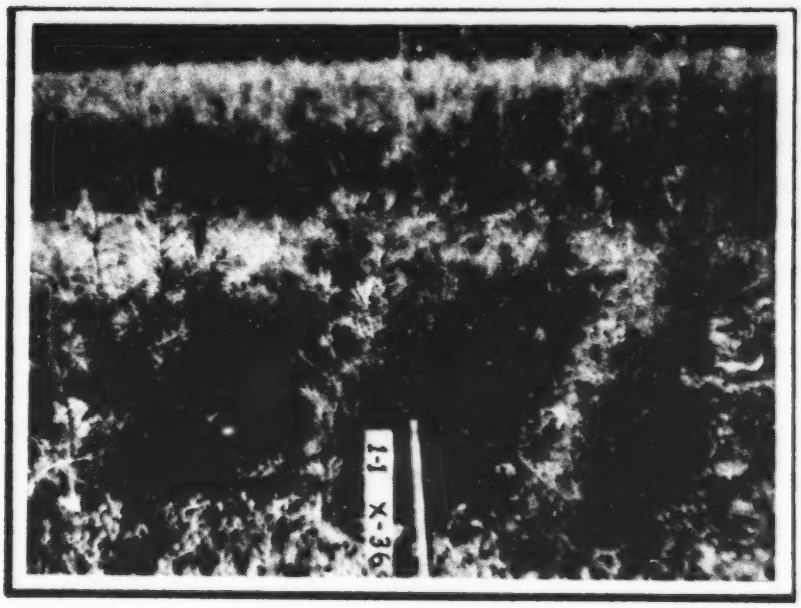
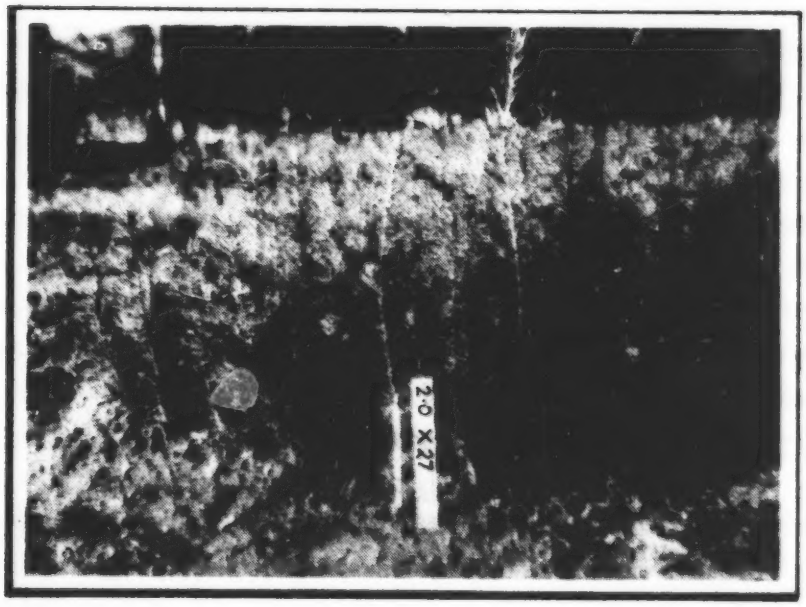


FIGURE 1. Douglas-fir stock types at the Duncan nursery in March 1962, just before planting.


1.1 X-36


2.0 X27

Unfortunately, buffer rows between plots and the surrounding forest and between rows within each plot were not established.

Survival and height growth were assessed in the fall of 1962, spring of 1963, and fall of 1964. A report was prepared following the 1964 assessment[2]. Results indicated no significant differences in survival and growth between 1+1 and 2+0 stock types; however, autumn-sown 1+0 stock type had significantly lower survival and growth than 1+1 or 2+0 stock types, and spring-sown 1+0 stock type was significantly poorer than autumn-sown 1+0 stock type. Autumn-sown 1+0 stock type from seedlot B2/467/59 had significantly better survival and growth than that from seedlot B2/404/59.

Differences in survival and growth were significant between north and south aspects and increased in the 1+0 stock types (autumn and spring). Survival was higher on north aspects, but initial leader growth was longer on south aspects.

Only minor differences in survival were recorded between the three burning histories, although significantly longer leader growth was measured on old burns.

The weather during the first 3 years was considered exceptionally favourable for stock survival and initial height growth. It was suggested that the indicated differences between stock types and aspects would be greatly enlarged under average or unfavourable conditions.

The final file report concluded that it was doubtful that significant differences in total height or current leader growth among stock types would remain after 5 years. Revel expected that the difference in size of planted stock, having a strong influence on growth during the first 3 years, would rapidly disappear as site edaphic and climatic factors became dominant.

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[2]W.J. Revel. 1964. Comparison of four age-classes of Douglas-fir planting stock on various sites. E.P. 586 Draft Final Report. B.C. Forest Service, Research Division, Victoria, B.C.

1.1 Rationale for Remeasurement

The fact that different stock types have different survival and growth rates after outplanting has been known to silviculturists for a long time. Many previous stock type trials conducted with Douglas-fir in Oregon, Washington, and British Columbia have shown that large, stocky seedlings with low shoot-root ratio have higher survival and initial shoot growth than small seedlings (Daniel et al. 1979; Cleary et al. 1980). In almost all cases stock type trials were assessed for 5-10 years after outplanting. After that time it was assumed that the difference in size among stock types disappears under the influence of the common conditions of the planting site. Should the difference among stock types persist for decades (or possibly for the whole rotation) then production of vigorous large stocky seedlings may be even more critical.

This project offered a unique opportunity to assess a well-established stock type trial after 21 years. The initial field inspection of the experimental plots in 1983 indicated that there were considerable differences in survival and height among stock types.

A disadvantage of the study was that some outdated stock types no longer in use were also assessed. However, this is inevitable in stock type trials established decades ago. Other shortcomings include: the description of stock used is not as complete as is presently required; planting density is too high compared to the present standard (9260 versus 1200 trees per hectare); and the plots lack buffer rows.

In spite of these deficiencies, the experiment was considered worth re-evaluation. Planted stock types originated from one seedlot and were grown under identical conditions in the same nursery. Physiological condition of the planted stock was good and relatively homogeneous as indicated by the survival after the first growing season (80-100% for all rows except one). The experiment was established over a broad range of forest sites examining three burning treatments.

1.2 Objectives

The objectives of the re-evaluation were:

- To evaluate, 21 years after plantation establishment, the differences in tree mortality, tree diameter, and tree height due to: 1) nursery stock type, 2) slashburning treatment, and 3) ecosystem association
- To evaluate the nutritional status of burned and unburned sites by foliar analysis.

2 LOCATION AND CLASSIFICATION OF EXPERIMENTAL PLOTS

The experimental plots are on south and north Vancouver Island: 10 plots are in the vicinity of Cowichan Lake, south of Honeymoon Bay (longitude 124°15', latitude 48°48'); 12 plots are west of Campbell River, in the vicinity of Upper Quinsam Lake (longitude 125°30', latitude 49°52').

The experimental plots were located in the Vancouver Island Drier Maritime Coastal Western Hemlock variant (CWHa1) (Klinka et al. 1984). Plots 3-121 and 5-212 were classified as transition between CWHa1 and the Leeward Montane Wetter Coastal Western Hemlock variant (CWHb4) (Klinka et al. 1984). These two plots had abundant natural regeneration of western hemlock, Pacific silver fir, and yellow-cedar, with all three species rapidly outgrowing planted Douglas-fir.

Two hygrotope-trophotope classifications were derived (Appendix 5): one identified in the field and one derived through computerized integrated site diagnosis[3]. The computerized data analysis verified field classification for most plots. The discrepancies were carefully evaluated and final hygrotope-trophotope was determined (Appendix 5).

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[3]S. Johnson. 1984. Site diagnosis, a field application. Misc. Mimeo. Fac. Forestry, University of B.C., Vancouver, B.C.

In Campbell River, the moisture regime of the unburned plots (hygrotope 3-4) was rated higher than the moisture regime of the fresh burned plots (hygrotope 2-3). Old burned plots were classified as intermediate between unburned and fresh burned. Nutrient regime (trophotope) of all plots was similar. In Lake Cowichan the unburned and fresh burned sites had similar moisture and nutrient regimes.

The north facing plots at both locations had slightly better moisture status (by approximately one unit) than the south facing plots.

3 METHODS

3.1 Field Data Collection

Detailed maps that show the exact plot location were provided by Revel[4]. Only 21 of the 24 plots established in 1962 were located and remeasured. Old burned plots established near Lake Cowichan, two on the north and one on the south aspect, were either not found or were inaccessible.

3.1.1 Site description

Description of site, vegetation, and soil was recorded on each plot, using the Ecological Classification Reconnaissance Forms commonly used by the B.C. Ministry of Forests.

Vegetation cover on each plot and in the immediate vicinity was described by strata (trees, shrubs, herbs, mosses, and lichens). Soil description was based on one soil pit per plot located 2-3 m outside of, but close to, the middle of the long axis of the plot. Soil was classified according to the Canadian System of Soil Classification (Canadian Soil Survey Committee 1978), and humus according to the humus form classification proposed by Klinka et al. (1981).

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[4]Revel, 1962.

3.1.2 Tree mensuration.

Tree diameters (dbh) were measured with a steel tape at 1.3 m above ground on all living trees in the experimental plots. Tree heights were measured with a 12 m long height pole to the nearest 0.1 m. Tree heights were measured on a sample of approximately 10 to 25 trees per row (approximately one-third to one-half of living trees). Trees for height measurement were selected randomly from 3-cm diameter strata classes.

3.1.3 Foliar samples.

Foliar samples were collected in the last week of October 1983. Samples were collected only from trees that originated from the B2/404/59 seedlot. Two dominant trees from each of four rows on each plot were felled and current year foliage was collected from the third whorl from the top. Trees were selected to represent the upper and lower half of each row.

3.2 Data Analyses

3.2.1 Site classification

Biogeoclimatic subzones or variants were identified from the map of biogeoclimatic units (Klinka et al. 1979, Nootka-Nanaimo sheet 92 SW). Hygrotope and trophotope of each plot were determined using the key proposed by Green (Klinka et al. 1984), and according to dominant plant cover[5] (Klinka et al. 1984). A computerized site diagnosis was conducted after Johnson[6].

3.2.2 Foliar analyses

Foliar samples by individual trees were analysed on one fresh burned and one unburned plot at both Lake Cowichan and Campbell River to determine the variability between rows and within rows.

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[5]K. Klinka. 1977. Guide for tree species selection and prescribed burning in the Vancouver Forest District. An abbreviated version. B.C. Min. For., Vancouver Forest District, Vancouver, B.C.

[6]Johnson, 1984.

To reduce the number of chemical analyses, foliar samples were composited into one sample per plot on the remaining 17 plots.

Samples were oven-dried (within 36 hours after collection) and analysed for macronutrient concentrations (N, P, S, K, Ca, Mg) with the use of standard analytical methods for foliar samples.

3.2.3 Statistical analyses

The layout of the experiment is depicted schematically in Table 1. As indicated earlier, some plots were not found, thus making the design unbalanced. Analysis based on contrasts (Cochran and Cox 1957; Kepel 1973; Montgomery 1976) were used to test the equality of means of tree survival, dbh, height, and foliar nutrient concentration (Appendix 1). The results of the analyses are shown in Appendix 2 and 4. The percent survival data were arcsine square root transformed before analysis. Duncan's multiple range test was performed on the significant tests.

4 RESULTS

4.1 Stock Type Performance

The differences in survival and height among stock types have persisted 21 years after planting (Table 2 and Appendix 2).

There were no significant differences in survival, height, and dbh between 1+1 and 2+0 stock types; however, both 1+0 stock types from seedlot 404 had signficantly lower survival, height, and dbh than 1+1 or 2+0 stock types (Table 2). Spring-sown 1+0 stock type had significantly lower survival and height than autumn-sown 1+0 stock type from seedlot 404, but equivalent dbh.

Autumn-sown 1+0 stock type from seedlot 467 was comparable to stock types 2+0, 1+1, and 1+0A (seedlot 404) in survival; to stock types 1+1 and 1+0A (seedlot 404) in height; and to stock types 2+0 and 1+1 in dbh.

TABLE 1. Schematic design of the experiment

Location	Campbell River						Cowichan Lake					
Burning	No		Fresh		Old		No		Fresh		Old	
Aspect	N	S	N	S	N	S	N	S	N	S	N	S
Replicas	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2
Stock 1	50[a]											
2	50											
3	50										missing plots	
4	50											
5	50											

[a] Number of seedlings.

TABLE 2. Mean survival, diameter, and height of stock types after the 21st growing season

Stock type	Seedlot	n	Mean dbh (cm)		Mean H (m)		Mean surv. %	
1. 2+0	404	21	5.68	a[a]	8.06	a	92.0	a b
2. 1+1	404	21	5.67	a	7.96	a b	94.2	a
3. 1+0A[b]	404	21	5.27	b	7.26	c	88.9	b
4. 1+0	404	21	5.12	b	6.75	d	79.9	c
5. 1+0A	467	21	5.62	a	7.62	b c	90.9	a b
	SE		0.092		0.14		1.3[c]	

[a] Means with identical letters are not significantly different at the 0.05% level.
[b] 1+0A - Autumn-sown stock
[c] Standard error (SE) of survival is an approximated value. Transformed SE=0.02498.

4.2 Site Preparation

The differences in tree survival, height, and diameter among the three burning treatments were not statistically significant (Table 3). Foliar nutrient concentrations were rated according to the nutrient deficiency scale for Douglas-fir proposed by Ballard[7]. All plots were found to be nitrogen deficient (Appendix 3). Two plots, one unburned and one fresh burned were very severely deficient, most plots were severely to moderately deficient, and some plots were moderately to slightly deficient. The four fresh burned plots in Campbell River had the best nitrogen status; three of them were close to the value considered as sufficient nitrogen status. However, the burned plots in Lake Cowichan did not behave the same way. Foliar concentrations of P, K, Ca, and Mg indicated no deficiency on any plot.

Significant differences in foliar nutrient concentrations between unburned and fresh burned sites and between south and north aspects were not detected (Appendix 4). However, when Campbell River plots were analysed alone, foliar nitrogen concentrations on freshly burned plots were significantly higher than on old burned and unburned plots (Table 4).

No significant differences in foliar nutrient concentrations among the four stock types were detected.

Foliar concentrations of N, P, K, and Ca were significantly different between Lake Cowichan and Campbell River plots (Table 5).

4.3 Aspect and Location

Survival, height, and diameter did not differ significantly between north and south aspects or between Campbell River and Lake Cowichan (Appendix 2).

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[7]T.M. Ballard. 1982. Foliar analysis research. E.P. 889 Contract Report. B.C. Min. For., Research Branch, Victoria, B.C.

TABLE 3. Mean survival, diameter, and height for three burning treatments for all stock types at all locations

Burning treatment	n	dbh (cm)	H (m)	Surv. %
Unburned	40	5.40 a[a]	7.06 a	87.3 a
Fresh burned	40	5.61 a	7.89 a	91.3 a
Old burned	25	5.37 a	7.72 a	90.9 a
SE[b]		0.21	0.63	2.8[c]

[a] Means with identical letters are not significantly different at the 0.05 level.
[b] Standard error is for a sample size of 40.
[c] Standard error of survival is an approximated value. Transformed SE=0.04716.

TABLE 4. Mean foliar nutrient concentrations (in percent) for three burning treatments at Campbell River

Burning treatment	N	P	K	Ca	Mg	S
Fresh burn	1.41 a[a]	0.22 a	0.69 a	0.49 a	0.15 a	0.13 a
Old burned	1.28 b	0.20 a	0.69 a	0.46 a	0.14 a	0.12 a
Unburned	1.22 b	0.19 a	0.74 a	0.45 a	0.14 a	0.12 a
SE	0.055	0.015	0.031	0.022	0.008	0.006

[a] Means with identical letter are not significantly different at the 0.05% level. Sample size is four for each mean.

TABLE 5. Mean foliar nutrient concentrations (in percent) for Campbell River and Lake Cowichan locations (unburned and fresh burned plots)

Location	N	P	K	Ca	Mg	S
Campbell River	1.31 a[a]	0.21 a	0.71 a	0.47 a	0.14 a	0.13 a
Lake Cowichan	1.18 b	0.25 b	0.82 b	0.35 b	0.13 a	0.12 a
SE	0.039	0.010	0.022	0.016	0.005	0.004

[a] Means with identical letter are not significantly different at the 0.05% level. Sample size is eight for each mean.

5 DISCUSSION

5.1 Stock Type

The differences in survival and height among the five tested stock types 21 years after planting remain very similar to the differences observed 3 years after planting. The 1+0 stock types (seedlot 404) are still significantly smaller than the 2+0 and 1+1 stock types. The 1+0 spring-sown stock type is significantly smaller and nas a lower survival rate than 1+0 autumn-sown stock type from seedlot 404 (Table 2).

Most of the seedling mortality occurred during the first 3 years. Only approximately 2% percent of the seedlings died between the third and 21st growing season and the mortality during that period was very similar for all five stock types (Tables 7 and 8).

Inspection of experimental plots in 1983 revealed a visible difference in height among stock types. The initial relative difference in height of some stock types was large: stock type 2+0 was almost three times as tall as stock type 1+0 (Table 6). The first season height growth was also highly variable: stock type 1+1 was the fastest growing and grew twice as fast as stock type 1+0. However, the relative difference in stock type height decreased considerably after the third growing season (Table 7): stock type 1+0 attained 56% of the height of stock type 2+0. The 3rd-year leader growth of different stock types also became less variable, as stock type 1+0 attained 71% of the leader growth of stock type 1+1. The difference in stock type height further declined over the next 18 years and after the 21st growing season the height difference between the tallest (2+0) and shortest (1+0) stock types was 16% (Table 8). The small stock types grew relatively faster than the large stock types.

While the relative difference in the stock type height was decreasing, the absolute difference was increasing. The initial absolute height difference between the shortest (1+0) and the tallest (2+0) stock type was 11.1 cm. This difference increased to 17.4 cm after the third growing season, and to 131 cm after the 21st growing season. The absolute

TABLE 6. Mean initial stock type height, mean leader growth, and survival after the first growing season[a]

	Stock type	Seedlot	Initial height (cm)	1st-year leader growth (cm)	Survival %
1.	2+0	404	17.59 (100)[b]	5.33 (93)	97
2.	1+1	404	11.32 (64)	5.76 (100)	98
3.	1+0A	404	10.37 (59)	3.17 (55)	96
4.	1+0	404	6.28 (36)	3.02 (52)	92
5.	1+0A	467	11.46 (65)	3.47 (60)	98

[a] B.C. Min. For., Research Branch, Victoria, B.C. E.P. 586 file data.
[b] Percent of the largest value.

TABLE 7. Mean survival, height, and leader growth after the third growing season[a]

	Stock type	Seedlot	Height (cm)	3rd-year leader growth (cm)	Survival %
1.	2+0	404	39.93 (100)	15.24 (98)	95
2.	1+1	404	35.66 (89)	15.54 (100)	96
3.	1+0A	404	28.35 (71)	12.19 (78)	90
4.	1+0	404	22.56 (56)	10.97 (71)	82
5.	1+0A	467	31.09 (78)	13.41 (86)	94

[a] From: W.J. Revel. 1964. Comparison of four age-classes of Douglas-fir planting stock on various sites. E.P. 586 Draft Final Report. B.C. Forest Service, Research Division, Victoria, B.C.

TABLE 8. Mean survival, height, dbh, and estimated stem volume after the 21st growing season

	Stock type	Seedlot	Height (m)	dbh (cm)	Estimated tree stem volume (cm^3)	Survival %
1.	2+0	404	8.06 (100)	5.68 (100)	6808 (100)[a]	92
2.	1+1	404	7.96 (99)	5.67 (100)	6700 (98)	94
3.	1+0A	404	7.28 (90)	5.27 (93)	5293 (78)	89
4.	1+0	404	6.75 (84)	5.12 (90)	4632 (68)	80
5.	1+0A	467	7.62 (95)	5.61 (99)	6278 (93)	91

[a] Mean tree stem volumes were calculated using constant form factor volume equation $V=b\ D^2H$ where $b=\pi/3.2^2$.

difference in the length of tree leader also increased with age. The 1st-year difference between the shortest (1+0) and the tallest (1+1) leader was 2.7 cm; the 3rd-year difference was 4.6 cm. Unfortunately, it was not feasible to measure 21st-year leader growth, and therefore, the current rate of growth cannot be compared.

Stem caliper was not measured at the time of planting and therefore the change in tree diameter over age cannot be discussed. Tree diameter (dbh) after the 21st growing season is less variable than tree height. The relative difference between the smallest (1+0) and the largest (2+0) stock stype is 10%; the absolute difference is 0.6 cm.

The mean tree stem volume was estimated for each stock type from mean height and mean dbh for the stock type (Table 8). The relative difference in estimated volume between the smallest (1+0) and the largest (2+0) stock type is 32%; the absolute difference is 2176 cm^3.

The persistent difference in stock type height after planting is consistent with results of some other studies. Van den Driessche (1984) found a good correlation between seedling dry weight and subsequent survival and height growth after planting in coastal Douglas-fir; the stock size differences attained in the nursery were maintained for 3 years after planting in the forest with little relative change. With Douglas-fir, Pendl and D'Anjou[8] found that the difference between large transplanted stock types (1+2 and 2+1) and smaller bareroots (2+0) remained 15-17 years after planting, with differences in height and diameter being statistically significant. In Ontario, larger transplanted stock (2+2) of red pine, white pine, white spruce, and black spruce were 11-16% taller on experimental plots and 12-22% taller in operational plantations than were smaller bareroot stock (3+0) 15 years after planting (Mullin 1980).

How long the height difference among experimental stocks will persist can not be answered at present. Revel[9] concluded in his report that differences in total height and current leader growth would disappear in

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[8]F. Pendl and B. D'Anjou. 1983. Survival and early growth of morphologically defined classes of Douglas-fir on high site lands. E.P. 589. File final report. B.C. Ministry of Forests, Research Section, Vancouver Region.

[9]Revel, 1964.

the future, as stock types adjust to site environment. Revel's conclusion is supported by van den Driessche (1984), who found that different stock types develop similar morphological characteristics after planting as they adjust to a common environment. The results of this study indicate that the relative height difference among stock types is decreasing with time, but that the absolute height difference is increasing.

The application of the persisting height difference between large and small Douglas-fir stock types is mainly in management of brush sites. Large stock types are expected to grow faster and thus outgrow brush sooner than smaller stock types.

5.2 Site Preparation

The majority of the burned plots were classified as moderately dry (hygrotope 2-3), with medium to poor nutrient regime and high to medium sensitivity to fire according to slashburning guidelines proposed by Klinka et al. (1984). Because the majority of unburned plots had a better moisture regime (hygrotope 3-4) than the burned plots (Appendix 5), a poorer growth on burned than on unburned sites was expected. However, the differences in the three burning treatments were not statistically or practically significant 21 years after planting. Detrimental effect of slashburning was not detected in this experiment.

5.3 Site Effect

The difference in mean tree height among the experimental plots is considerable; however, this difference does not appear to be related to either location (north or south Vancouver Island), aspect (north or south), burning treatment (burned or unburned), or site unit (Table 9). The difference in tree height between most replicates is statistically significant at the 5% level. Only in three replicates (plot no. 1 and 2; 3 and 4; 7 and 8) is the difference not statistically significant (Table 9). Perhaps microsite variability and different intensities of burning caused the differences in tree heights between replicates.

TABLE 9. Mean tree height and foliar nitrogen status related to ecosystem classification

Plot[a] no.	Plot[b] code	n	H (SE) (m)	N-Status[c]	H/T[d]	Site[e] Unit
9	5 211	100	10.05 (0.25) a[f]	S-MD	4C	2/4
21	11 321	103	9.89 (0.23) a	S-MD	4D	5
14	7 222	101	9.53 (0.22) a	S-MD	3C	2/3
16	8 222	101	8.94 (0.20) b	M-SD	2-3C	2
6	3 122	101	8.47 (0.25) bc	S-MD	3C	2/4
4	2 112	112	8.44 (0.23) bc	S-MD	4B-C	4
11	6 211	92	8.29 (0.24) c	M-SD	3B-C	2/4
10	5 212	112	8.22 (0.18) c	S-MD	3C	2/4
23	12 321	105	8.20 (0.17) c	S-MD	3B-C	2
20	10 312	112	8.01 (0.26) dc	M-SD	2B-C	2
7	4 121	95	7.98 (0.18) dc	S-MD	3B-C	2/4
3	2 111	106	7.91 (0.22) dc	S-MD	4B-C	4
15	8 221	95	7.84 (0.20) dc	M-SD	2C	2
8	4 122	86	7.38 (0.21) d	S-MD	3C	2/4
12	6 212	88	6.50 (0.21) e	M-SD	2C	2
19	10 311	81	6.30 (0.24) e	S-MD	4C	4/5
24	12 322	106	6.27 (0.22) e	S-MD	3B-C	2
2	1 112	100	6.22 (0.22) e	M-SD	4C-D	5
1	1 111	93	6.16 (0.23) e	VSD	4C	4/5
5	3 121	101	4.15 (0.14) f	S-MD	2C	2
13	7 221	78	4.03 (0.15) f	VSD	2B	2

[a] Plots 17 (9 311), 18 (9 312), and 22 (11 322) were not located and remeasured.

[b] The first number (one or two digits) indicates location (odd: Lake Cowichan, even: Campbell River); the second number indicates burning treatment (1: unburned, 2: fresh, 3: old burned); the third number indicates aspect (1: north, 2: south); the fourth number indicates replicate (first or second).

[c] N-status: nitrogen foliar concentration rating from Appendix 3.

[d] Hygrotope/trophotope on the edatopic grid.

[e] Site unit from edatopic grid.

[f] Means with identical letters are not significantly different at the 0.05% level.

The foliar nitrogen concentration is not well correlated with either mean tree height or hygrotope-trophotope classification. The height of trees on the experimental plots appears to be determined by factors that were not assessed in this experiment.

6 CONCLUSIONS

The following conclusions are drawn from the study:

- Type and size of planted stock significantly influenced the survival and size of Douglas-fir trees 21 years after planting.

- Seedlot significantly influenced diameter of trees.

- Slashburning treatment did not significantly influence tree survival, height, and diameter.

- Slashburning did not decrease foliar nitrogen concentration. In Campbell River, foliar nitrogen concentrations on burned sites were significantly higher than on unburned sites; in Lake Cowichan, differences between burned and unburned sites were not detected.

- The mean height of all stock types varied considerably among the experimental plots. This height difference was not related to location (north or south Vancouver Island), aspect (N or S), burning treatment (burned or unburned), and hygrotope-trophotope rating of the plots.

The above conclusions are valid for the sites of the experimental plots, investigated species, stock types, and burning treatments. Different sites, species, stock types, and burning treatments may yield different results.

7 RECOMMENDATIONS

- Large Douglas-fir stock should be used where large trees are desired soon.

- Since it is presently unclear whether the height difference among stock types is increasing or decreasing, the experimental project should continue until the differences among stock types disappear.

- Current leader growth should be assessed (when the plots are thinned) to determine if the five stock types differ in their height increment.

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APPENDIX 1. The four-way split-plot analysis of variance

Source[1]	df	Error
(Main Plot)		
Location	1	Rep (LSA)
Site Prep	2	"
Aspect	1	"
SxA	2	"
LxA	1	"
LxS	2	"
LxSxA	2	"
Error 1 (LSA)	12	
(Split Plot)		
Stock (T)	4	T x Rep (LSA)
TxS	8	"
TxA	4	"
TxSxA	8	"
TxL	4	"
TxLxA	4	"
TxLxS	8	"
TxLxSxA	8	"
Error 2 (LSA)	48	
	119	

[1] The main plot effects are tested against error 1 and the split plot effects are tested against error 2.

APPENDIX 2. Analysis of variance of row means

Source	df	dbh SS	dbh Prob.	Height SS	Height Prob.	Survival++ SS	Survival++ Prob.
Mainplot - Location, burn, and aspect	10	1122.66	0.75	10661.77	0.73	0.73574	0.62
1. Campbell R. vs. Lake Cowichan *	1	626.86	0.087	1341.83	0.38	0.06923	0.40
2. No burn vs. Recent Burn *	1	85.06	0.50	1398.52	0.37	0.08584	0.35
3. Old burn vs. Other Burn **	1	230.49	0.28	663.96	0.53	0.00427	0.83
4. North Aspect vs. South Aspect +	1	2.15	0.91	258.96	0.69	0.01178	0.72
5. Old burn at Lk. Cowichan vs. all others	1	4.54	0.88	2903.57	0.20	0.02266	0.62
6. Interactions	5	261.20	0.90	4542.23	0.72	0.45313	0.46
Error	10	1745.93	0.0001	15753.78	0.0001	0.88969	0.0001
Split-plot - Stock type	4	391.96	0.0012	2383.69	0.0001	0.55274	0.0001
1. 2-year-old vs. 1-year-old	1	217.74	0.0012	1580.96	0.0001	0.27131	0.0001
2. 2+0 vs. 1+1	1	0.15	0.93	10.31	0.63	0.00917	0.41
3. 1+0A vs. 1+0A	1	91.85	0.028	125.12	0.098	0.00716	0.46
4. 1+0S vs. 1+0A for same seedlot	1	9.37	0.47	237.19	0.025	0.16289	0.0011
5. Mainplot Interactions with Stock Type	40	964.81	0.17	1314.09	0.81	0.71069	0.17
i. Loc x Type (1. x Type)*	4	38.22	0.71	271.58	0.20	0.09896	0.13
ii. Burn x Type (2. x Type)*	4	67.27	0.44	180.84	0.40	0.02334	0.78
iii. Old Burn x Type (3. x Type)**	4	17.80	0.91	62.59	0.84	0.05286	0.41
iv. Aspect x Type (4. x Type)*	4	18.67	0.90	256.17	0.23	0.16530	0.024
Error	40	710.25	-	1745.03	-	0.52396	-
TOTAL	104	5101.26	-	31858.34	-	3.477166	-

Where prob. is lower than 0.05, the difference is significant.

* Old burn data not included.
** Only Campbell River data.
\+ The one old burn plot at Lake Cowichan not included.
++ Arcsine square root transformation of percent survival was used.

NOTE: Contrasts are not necessarily orthogonal.

APPENDIX 3. Foliar nitrogen concentrations (composited samples or mean from individual tree samples)

Plot code	Location[1]	Burn[2]	Aspect[3]	N %	N-status[4] (Ballard 1982)
1-111	L.C.	N.B.	N	1.01	VSD
1-112	L.C.	N.B.	N	1.34	M-SD
2-111	C.R.	N.B.	N	1.22	S-MD
2-112	C.R.	N.B.	N	1.14	S-MD
3-121	L.C.	N.B.	S	1.22	S-MD
3-122	L.C.	N.B.	S	1.22	S-MD
4-121	C.R.	N.B.	S	1.30	S-MD
4-122	C.R.	N.B.	S	1.23	S-MD
5-211	L.C.	F.B.	N	1.16	S-MD
5-212	L.C.	F.B.	N	1.23	S-MD
6-211	C.R.	F.B.	N	1.42	M-SD
6-212	C.R.	F.B.	N	1.42	M-SD
7-221	L.C.	F.B.	S	0.97	VSD
7-222	L.C.	F.B.	S	1.29	S-MD
8-221	C.R.	F.B.	S	1.35	M-SD
8-222	C.R.	F.B.	S	1.44	M-SD
10-311	C.R.	O.B.	N	1.27	S-MD
10-312	C.R.	O.B.	N	1.37	M-SD
11-321	L.C.	O.B.	S	1.18	S-MD
12-321	C.R.	O.B.	S	1.25	S-MD
12-322	C.R.	O.B.	S	1.22	S-MD

[1] Location - L.C. - Lake Cowichan, C.R. - Campbell River.
[2] Burn - N.B. - not burned, F.B. - fresh burn, O.B. - old burn.
[3] Aspect - N-North, S-South.
[4] N-status: very severely deficient (VSD) 0 - 1.05%.
severely to moderately deficient (S-MD) 1.05 - 1.30%.
moderately to slightly deficient (M-SD) 1.30 - 1.45%.
no deficiency (ND) 1.45% and higher.

Reference: Ballard, T.M. 1982: Foliar analysis research. E.P. 889 Contract Report. B.C. Min. For. Research Branch, Victoria, B.C.

APPENDIX 4. Analysis of variance on foliar nutrient concentrations

Source	df	Nitrogen SS	Nitrogen Prob.	Phosphorus SS	Phosphorus Prob.	Potassium SS	Potassium Prob.	Calcium SS	Calcium Prob.	Magnesium SS	Magnesium Prob.	Sulphur SS	Sulphur Prob.
Treatment	10	17.165	0.29	19.031	0.11	12.848	0.03	7.057	0.027	28.668	0.40	10.544	0.63
1. Campbell R. vs. L. Cowichan*	1	17.172	0.036	6.806	0.018	4.690	0.0055	5.2470	0.0004	3.399	0.26	0.141	0.75
2. No burn vs. fresh Burn*	1	2.203	0.21	2.438	0.12	1.109	0.12	0.0881	0.52	2.540	0.33	1.000	0.40
3. Old Burn vs. others (C.R.)**	1	0.366	0.60	0.044	0.82	0.158	0.53	0.0310	0.70	0.344	0.71	0.032	0.88
4. North vs. South+	1	0.049	0.85	1.620	0.20	0.856	0.16	0.0439	0.64	1.070	0.52	0.113	0.78
5. Old burnout L.C. vs. Others	1	0.516	0.53	0.733	0.37	1.792	0.054	0.010	0.82	1.273	0.48	0.250	0.43
6. Interactions+	5	7.101	0.39	6.149	0.29	1.655	0.53	0.9979	0.45	12.466	0.45	9.419	0.29
i) Loc x Aspect	1	0.163	0.72	5.077	0.034	1.019	0.13	0.0438	0.64	1.485	0.45	3.754	0.12
ii) Loc x No and Fresh Burn	1	4.881	0.073	0.066	0.79	0.000	0.99	0.2110	0.32	0.048	0.89	4.254	0.10
Error	10	12.175	-	8.448	-	3.769	-	1.9418	-	24.133	-	13.047	-
Total	20	29.341		27.479		16.617		8.999		52.801		23.591	

* Old burn data not included
** Only Campbell River data
\+ The old burn plot at Lake Cowichan not included

Where prob. is lower than 0.05, the difference is significant

APPENDIX 5. Site and soil description and hygrotope-trophotope for experimental plots

Sample[1] plot code	Elev.[2] m	Site description Slope %	Aspect[3]	M.S.P.[4]	Texture[5] B-horizon	Depth[6]	Soil description Coarse[7]	Drain[8]	Ter. class[9]	Field[10] H/T	Integer[11] H/T	Final[12] H/T	Site unit
2 111	590	57	NW 320	Mid.	SL	80+	20	well	1 MGb	4/C	(3)-4/B-C	4/B-C	4
2 112	555	53	N 0	Mid.	SL	95+	20	well	1 MGb	4/C	4/B-C	4/B-C	4
4 121	530	52	S *	Mid.	LS	80+	20	well	S MGb	3/C	(3)-4/B-C	(4)-3/C-B	2/4
4 122	535	38	S 180	Low	LS	90+	*	well	S MGb	3/C	(4)-5/C	(4)-3/C	2/4
6 211	570	40	N 15	Mid.	S	80+	35	well	S MGb	3/C	3/B-C	3/B-C	2/4
6 212	545	25	N 0	Mid.	SL-LS	60	35-75	rapid	S MGb	2/B	2-(3)/C	2-(3)/C	2
8 221	590	30	S 195	Mid.	LS	65+	50	well	S MGb	2/B	2-(3)/C	2-(3)/C	2
8 222	580	30	S 195	Mid.	S	55	45	well	S MGb	2/B	2-(3)/C	2-(3)/C	2
10 311	480	47	N 0	Low	L	100	70	well	1 MGb	3-4/C	(4)-5/C	(3)-4/C	4/5
10 312	425	54	N 340	Upper	S	80	50	rapid	S Mfv	2/B	2/B-C	(3)-2/C-B	2
12 321	415	30	S 180	Mid.	LS	100+	40	well	S MGb	3/B	(2)-3/B-C	(2)-3/B-C	2
12 322	480	40	SW 210	Low	SL	38	45	rapid	S CV	2/B	4/B-C	(2)-3/B-C	2
1 111	550	45	N 10	Mid.	L	40	35	mod-well	Z MGv	4/D	4/C	4/C	4/5
1 112	620	65	NW 330	Mid.	L	100	60	well	Z-SK MGb	4/D	(3)-4/C-D	4/C	5
3 121	640	15	S 195	Upper	LS	70	65	rapid	SK MGb	2/B	2/C	2/C	2
3 122	613	32	W 250	Mid.	L	85	15	mod-well	Z MGb	4/C	3/C	3/C	2/4
5 211	650	70	E 80	Mid.	L	140+	10	well	Z MGb	3/C	4/C	4/C	2/4
5 212	660	35	E 75	Mid.	L	70	35	well	Z MGb	3/C	3-4/B-C	3-4/C-B	2/4
7 221	600	42	SW 240	Mid.	S	80	70	rapid	S MGb	2/B	3/C	2/B	2
7 222	690	40	SW 240	Mid.	SL	90+	35	well	Z-Sk MGb	3/C	3/C	3/C	2/3
11 321	530	45	W 250	Mid.	L	80+	10	mod-well	Z MGb	4/C	4/D	4/(D)-C	5

* missing value

1 Plots labeled with sample plot code starting with even number are located in Campbell River area, those starting with odd number are located in Lake Cowichan area.
2 Elev. - elevation in metres.
3 Aspect - aspect orientation in degrees.
4 M.S.P. - meso slope position (upper, middle, lower slope).
5 Texture of B-horizon - SL - sandy loam
LS - loamy sand
S - sand
L - loam
6 Depth - depth to C-horizon.
7 Coarse - percent of coarse fragment, gravel, coooles, stones.
8 Drain. - drainage class.
9 Ter. Class - terrain classification (Canadian Soil Survey Committee 1978).
10 Field H/T - hygrotope and trophotope as identified in field.
11 Integer. H/T - integrated hygrotope and trophotope (Johnson 1984).
12 Final H/T - final hygrotope and trophotope used for identification of site unit (Klinka et al. 1985).